

We claim:

1. An electrical device which comprises

- (1) a first laminar electrode;
- (2) a second laminar electrode; and
- (3) a laminar resistive element which exhibits PTC behavior, and which has a first face to which the first electrode is secured and an opposite second face to which the second electrode is secured;

the device comprising

(a) a main portion which comprises

- (i) a main part of the first electrode,
- (ii) a main part of the second electrode, and
- (iii) a main part of the resistive element;

and

(b) a first connection leg which extends away from the main portion and which comprises

- (i) a first leg part of the first electrode which is integral with the main part of the first electrode, and
- (ii) a first leg part of the resistive element which is integral with the main part of the resistive element.

2. A device according to claim 1 which also contains

- (c) a second connection leg which extends away from the main portion, which is spaced away from the first connection leg, and which comprises

- (i) a second leg part of the second electrode which is integral with the main part of the second electrode, and
- (ii) a second leg part of the resistive element which is integral with the main part of the resistive element.

3. A device according to claim 2 wherein

the main portion and the first and second connection legs are substantially coplanar,

the first and second connection legs extend away from the main portion in substantially the same direction so that they can both be mounted on a planar substrate with the main portion of the device extending away from the substrate;

the first connection leg comprises a first distal sub-portion spaced away from the main portion of the device and a first stand-off sub-portion which lies between the first distal sub-portion and the main portion, and

the second connection leg comprises a second distal sub-portion spaced away from the main portion of the device and a second stand-off sub-portion which lies between the second distal sub-portion and the main portion,

the distal and stand-off sub-portions being shaped so that when each of the distal sub-portions is placed in an aperture of an appropriate size in the planar substrate, the stand-off sub-portions will not pass through the apertures and will prevent contact between the substrate and the main portion of the device.

4. A device according to claim 3 wherein each of the first and second connection legs is wedge-shaped or includes a step which lies at the junction between the distal and stand-off sub-portions.

5. A device according to claim 2 wherein

the first connection leg contains a first leg part of the second electrode which is integral with the main part of the second electrode;

the second connection leg contains a second leg part of the first electrode which is integral with the main part of the first electrode;

the first leg part of the first electrode, the first leg part of the resistive element, and a first leg part of the second electrode are substantially coextensive; and

a second leg part of the first electrode, the second leg part of the resistive element, and the second leg part of the second electrode are substantially coextensive.

6. A device according to claim 3 wherein

the first stand-off sub-portion comprises a first bridge sub-portion which extends across the width of the first connection leg and which does not include any part of the second electrode;

and the second stand-off sub-portion comprises a second bridge sub-portion which extends across the width of the second connection leg and does not include any part of the first electrode.

7. A device according to claim 6 wherein

the first distal sub-portion comprises a second residual conductive member which, in the absence of the first bridge sub-portion, would be integral with the main part of the second electrode;

the second distal sub-portion comprises a first residual conductive member which, in the absence of the second bridge sub-portion, would be integral with the main part of the first electrode;

the second residual conductive member is separated from the second electrode by a distance which is at least as great as the minimum distance between the first and second electrodes at any location on the device; and

the first residual conductive member is separated from the first electrode by a distance which is at least as great as the minimum distance between the first and second electrodes at any location on the device.

8. A device according to claim 2 wherein the laminar resistive element is composed of conductive polymer and each of the electrodes is a metal foil.

9. A device according to claim 8 which has a resistance at 23°C of less than 50 ohm.

10. A device according to claim 1 wherein the laminar resistive element is composed of conductive polymer, each of the electrodes is a metal foil, and the first connection leg comprises

- (i) a first distal sub-portion which
  - (a) is spaced away from the main portion of the device,
  - (b) comprises a first distal sub-part of the first leg part of the first electrode, and
  - (c) comprises a first electrical connector which contacts the first distal sub-part of the first electrode and extends at least to the second face of the laminar resistive element;and
- (ii) a first bridge sub-portion which
  - (a) lies between the first distal sub-portion and the main portion of the device,
  - (b) extends across the width of the first connection leg, and
  - (c) does not include any part of the second electrode;

whereby the device can be placed flat on a planar insulating substrate having first and second appropriately spaced-apart metal conductors on the surface thereof, with the first electrical connector against the first metal conductor, and electrical connection can be made (a) between the first metal conductor and the first electrode, through the first electrical connector, and (b) between the second conductor and the second electrode.

11. A device according to claim 10 wherein the first distal sub-portion comprises a second residual conductive member which is on the second face of the first leg part of the resistive element and which, in the absence of the first bridge sub-portion, would be integral with the

main part of the second electrode, and the first electrical connector is a U-shaped member which extends around the end of the first leg portion and contacts the first electrode and the second residual conductive member.

12. A device according to claim 10 which also contains

a second connection leg which extends away from the main portion of the device;  
which is spaced apart from the first connection leg; which comprises

- (i) a second leg part of the second electrode which is integral with the main part of the second electrode, and
- (ii) a second leg part of the resistive element which is integral with the main part of the resistive element;

and which comprises

- (i) a second distal sub-portion which
  - (a) is spaced apart from the main portion of the device,
  - (b) comprises a second distal sub-part of the second leg part of the second electrode, and
  - (c) comprises a second electrical connector which contacts the second distal sub-part of the second electrode and extends at least to the first face of the laminar resistive element;

and

- (ii) a second bridge sub-portion which
  - (a) lies between the second distal sub-portion and the main portion of the device,
  - (b) extends across the width of the second connection leg, and
  - (c) does not include any part of the first electrode;

whereby the device can be placed flat on a planar insulating substrate having first and second appropriately spaced apart metal conductors on the surface thereof, with either the first electrical connector or the second electrical connector against one of the metal conductors, and electrical connection can be made between (a) said electrical connector and metal conductor and (b) the other metal conductor and the electrode adjacent to the substrate.

**13. A device according to claim 12 wherein**

the first distal sub-portion comprises a second residual conductive member which is on the second face of the first leg part of the resistive element and which, in the absence of the first bridge sub-portion, would be integral with the main part of the second electrode,

the second distal sub-portion comprises a first residual conductive member which is on the first face of the second leg part of the resistive element and which, in the absence of the second bridge sub-portion, would be integral with the main part of the first electrode;

the first electrical connector is a U-shaped member which extends around the end of the first leg portion and contacts the first electrode and the second residual conductive member; and

the second electrical connector is a U-shaped member which extends around the end of the second leg portion and contacts the second electrode and the first residual conductive member.

**14. A device according to claim 13 wherein the contacting surfaces of the first electrical connector, the first electrode and the second residual conductive member are such that these contacting surfaces can be soldered together by exposing them to heat; and the contacting surfaces of the second electrical connector, the second electrode and the first residual conductive member are such that these contacting surfaces can be soldered together by exposing them to heat.**

**15. A method of making an electrical device which comprises**

- (1) a first laminar electrode;**

- (2) a second laminar electrode; and
- (3) a laminar resistive element which exhibits PTC behavior has a first face to which the first electrode is secured and an opposite second face to which the second electrode is secured;

the device comprising

- (a) a main portion which comprises
  - (i) a main part of the first electrode,
  - (ii) a main part of the second electrode, and
  - (iii) a main part of the resistive element;
- (b) a first connection leg which extends away from the main portion and which comprises
  - (i) a first leg part of the first electrode which is integral with the main part of the first electrode, and
  - (ii) a first leg part of the resistive element which is integral with the main part of the resistive element; and
- (c) a second connection leg which extends away from the main portion, which is spaced away from the first connection leg, and which comprises
  - (i) a second leg part of the second electrode which is integral with the main part of the second electrode, and
  - (ii) a second leg part of the resistive element which is integral with the main part of the resistive element;

which method comprises

- (A) providing a planar laminate which comprises

- (1) a first laminar metal member;
  - (2) a second laminar metal member, and;
  - (3) a laminar resistive member which
    - (i) lies between the first and second members,
    - (ii) exhibits PTC behavior, and
    - (iii) is composed of conductive polymer;
- and
- (B) cutting a plurality of said electrical devices from the planar laminate.

16. An electrical assembly which comprises

- (A) an insulating substrate having a first aperture therein;
- (B) a first metal conductor secured to the insulating substrate and leading to the first aperture; and
- (C) an electrical device which comprises
  - (1) a first laminar electrode;
  - (2) a second laminar electrode; and
  - (3) a laminar resistive element which exhibits PTC behavior and which has a first face to which the first electrode is secured and an opposite second face to which the second electrode is secured;

the device comprising

- (a) a main portion which comprises
  - (i) a main part of the first electrode,



(ii) a main part of the second electrode, and

(iii) a main part of the resistive element;

and

(b) a first connection leg

which extends away from the main portion,

which comprises

(i) a first leg part of the first electrode which is integral with the main part of the first electrode, and

(ii) a first leg part of the resistive element which is integral with the main part of the resistive element, and

which has a first distal sub-portion spaced away from the main portion of the device and a first stand-off sub-portion between the first distal sub-portion and the main portion;

the first distal sub-portion including a first distal sub-part of the first electrode and lying within the first aperture of the substrate;

the first stand-off sub-portion lying between the substrate and the main portion of the device;

the first metal conductor being physically and electrically connected to the first distal sub-part of the first electrode; and

all of the electrical current between the first metal conductor and the second electrode of the device passing through the first electrode and the resistive element.

17. An assembly according to claim 16 wherein the insulating substrate has a second aperture therein; wherein a second metal conductor is secured to the insulating substrate and

leads to the second aperture; and wherein the device also contains a second connection leg which

- (a) extends away from the main portion,
- (b) is spaced away from the first connection leg,
- (c) comprises
  - (i) a second leg part of the second electrode which is integral with the main part of the second electrode, and
  - (ii) a second leg part of the resistive element which is integral with the main part of the resistive element, and
- (d) which has a second distal sub-portion spaced away from the main portion of the device and a second stand-off sub-portion between the second distal sub-portion and the main portion;

the second distal sub-portion including a second distal sub-part of the second electrode and lying within the second aperture of the substrate;

the second metal conductor being physically and electrically connected to the second distal sub-part of the second electrode; and

all of the electrical current between the second metal conductor and the first electrode of the device passing through the second electrode and the resistive element.

**18. An electrical assembly which comprises**

- (A) a planar insulating substrate;
- (B) a first metal conductor secured to the insulating substrate;
- (C) a second metal conductor secured to the insulating substrate; and
- (D) an electrical device which comprises

- (1) a first metal foil electrode;
- (2) a second metal foil electrode; and
- (3) a laminar resistive element which exhibits PTC behavior, which is composed of conductive polymer, and which has a first face to which the first electrode is secured and an opposite second face to which the second electrode is secured;

the device comprising

- (a) a main portion which comprises
  - (i) a main part of the first electrode,
  - (ii) a main part of the second electrode, and
  - (iii) a main part of the resistive element;and
- (b) a first connection leg  
which extends away from the main portion,  
which comprises
  - (i) a first leg part of the first electrode which is integral with the main part of the first electrode,
  - (ii) a first leg part of the resistive element which is integral with the main part of the resistive element,
  - (iii) a first distal sub-portion which  
is spaced away from the main portion of the device,

comprises a first distal sub-part of the first leg part of the first electrode, and

comprises a first electrical connector which contacts the first distal sub-part of the first electrode and extends beyond the second face of the laminar resistive element;

and

(iv) a first bridge sub-portion which

lies between the first distal sub-portion and the main portion of the device,

extends across the width of the first connection leg, and

does not include any part of the second electrode;

the device being placed generally parallel to the planar insulating substrate with the second electrode being closer to the substrate than the first electrode, the first electrical connector being connected to the first metal conductor; and the second conductor being connected to the second electrode.

19. An assembly according to claim 18 wherein the device also contains

a second connection leg which extends away from the main portion of the device; which is spaced apart from the first connection leg; which comprises

- (i) a second leg part of the second electrode which is integral with the main part of the second electrode, and
- (ii) a second leg part of the resistive element which is integral with the main part of the resistive element;

and which comprises

- (i) a second distal sub-portion which

-47-

- (a) is spaced apart from the main portion of the device,
- (b) comprises a second distal sub-part of the second leg part of the second electrode, and
- (c) comprises a second electrical connector which contacts the second distal sub-part of the second electrode and extends beyond the first face of the laminar resistive element;

and

- (ii) a second bridge sub-portion which
  - (a) lies between the second distal sub-portion and the main portion of the device,
  - (b) extends across the width of the second connection leg, and
  - (c) does not include any part of the first electrode;

and wherein the second conductor is connected to the second electrode through the second connector.

20. An assembly according to claim 18 wherein there is a solder joint between each of

- (a) the first electrical connector and the first electrode,
- (b) the first electrical connector and the first metal conductor, and
- (c) the second electrode and the second metal conductor, or between the second electrode and an intermediate connector which lies between the second electrode and the second metal conductor, and between the intermediate connector and the second metal conductor.

21. An assembly which comprises

- (1) a PTC resistive element which

-48-

- (a) is composed of a resistive material which exhibits PTC behavior,
  - (b) has a first face and a second face, and
  - (c) defines an aperture which runs between the first and second faces;
- (2) a transverse conductive member which
- (a) lies within the aperture defined by the PTC element,
  - (b) runs between the first and second faces of the PTC element, and
  - (c) is secured to the PTC element; and
- (3) a first laminar conductive member which (a) is secured to the first face of the PTC element and (b) is physically and electrically connected to the transverse conductive member.

22. A circuit protection device which has a resistance of less than 15 ohm and which comprises

- (1) a laminar PTC resistive element which
  - (a) is composed of a conductive polymer which has a resistivity at 25°C of less than 50 ohm-cm and which exhibits PTC behavior, and
  - (b) has a first face and second face;
- (2) a first metal foil electrode which contacts the first face of the PTC element;
- (3) a second metal foil electrode which contacts the second face of the PTC element; and
- (4) an additional metal foil conductive member which contacts the second face of the PTC element and is spaced apart from the second electrode;

the PTC element, the first electrode and the additional conductive member defining an aperture which runs between the first electrode and the additional conductive member, through the PTC element;

and

(5) a transverse conductive member which

- (a) is composed of metal,
- (b) lies within the aperture, and
- (c) is physically and electrically connected to the first electrode and the additional conductive member.

23. An electrical assembly which comprises

(A) a printed circuit board including first and second conductive traces on a surface thereof, and

(B) an electrical device which comprises

(1) a laminar PTC resistive element which

- (a) is composed of a resistive material which exhibits PTC behavior, and
- (b) has a first face and a second face;

(2) a first laminar electrode which is secured to the first face of the PTC element;

(3) a second laminar electrode which is secured to the second face of the PTC element;

(4) an additional laminar conductive member which (a) is secured to the second face of the PTC element and (b) is spaced apart from the second electrode;

the PTC element, the first electrode and the additional laminar conductive member defining an aperture which runs between the first electrode and the additional conductive member, through the PTC element; and

24. A method of making an electrical device which comprises

- (A) providing an assembly which comprises
  - (1) a laminar PTC resistive element which (i) is composed of a resistive material exhibiting PTC behavior, and (ii) has a first face and a second face,
  - (2) a first laminar conductive member which is secured to the first face of the PTC element, and
  - (3) a second laminar conductive member which is secured to the second face of the PTC element;
- (B) making a plurality of apertures through the thickness of the assembly provided in step (A), the apertures being arranged in a regular pattern;
- (C) simultaneously with step (B), or after step (B), placing a plurality of transverse conductive members within the apertures, in electrical contact with the first laminar conductive member;
- (D) removing predetermined portions of at least one of the first and second conductive members; and
- (E) after steps (A) to (D), dividing the assembly into a plurality of electrical devices, each device comprising
  - (1) a part of the PTC resistive element,
  - (2) a part of the first laminar conductive member, said part providing a first electrode in some of the devices and a second electrode in the other devices,
  - (3) a part of the second laminar conductive member, said part providing a second electrode in some of the devices and a first electrode in the other devices,



- (4) a residual part of the second laminar conductive member, and
- (5) at least one transverse conductive member which electrically connects the residual part and the first electrode.

25. An assembly which comprises

- (1) a laminar PTC resistive element which (i) is composed of a conductive polymer exhibiting PTC behavior, and (ii) has a first face and a second face,
- (2) a first laminar conductive member which is secured to the first face of the PTC element, and
- (3) a second laminar conductive member which is secured to the second face of the PTC element;

the PTC element and the first and second laminar conductive members defining a plurality of apertures which pass through the thickness of the assembly, and the apertures being arranged in a regular pattern.